

## Chapter 4 General Design Considerations

### 4-1. Freeboard

*a. Vertical distance.* The term freeboard is applied to the vertical distance of a dam crest above the maximum reservoir water elevation adopted for the spillway design flood. The freeboard must be sufficient to prevent overtopping of the dam by wind setup, wave action, or earthquake effects. Initial freeboard must allow for subsequent loss in height due to consolidation of embankment and/or foundation. The crest of the dam will generally include overbuild to allow for postconstruction settlements. The top of the core should also be overbuilt to ensure that it does not settle below its intended elevation. Net freeboard requirements (exclusive of earthquake considerations) can be determined using the procedures described in Saville, McClendon, and Cochran (1962).

*b. Elevation.* In seismic zones 2, 3, and 4, as delineated in Figures A-1 through A-4 of ER 1110-2-1806, the elevation of the top of the dam should be the maximum determined by either maximum water surface plus conventional freeboard or flood control pool plus 3 percent of the height of the dam above streambed. This requirement applies regardless of the type of spillway.

### 4-2. Top Width

The top width of an earth or rock-fill dam within conventional limits has little effect on stability and is governed by whatever functional purpose the top of the dam must serve. Depending upon the height of the dam, the minimum top width should be between 25 and 40 ft. Where the top of the dam is to carry a public highway, road and shoulder widths should conform to highway requirements in the locality with consideration given to requirements for future needs. The embankment zoning near the top is sometimes simplified to reduce the number of zones, each of which requires a minimum width to accommodate hauling and compaction equipment.

### 4-3. Alignment

Axes of embankments that are long with respect to their heights may be straight or of the most economical alignment fitting the topography and foundation conditions. Sharp changes in alignment should be avoided because downstream deformation at these locations would tend to produce tension zones which could cause concentration of seepage and possibly cracking and internal erosion. The

axes of high dams in narrow, steep-sided valleys should be curved upstream so that downstream deflection under water loads will tend to compress the impervious zones longitudinally, providing additional protection against the formation of transverse cracks in the impervious zones. The radius of curvature forming the upstream arching of the dam in narrow valleys generally ranges from 1,000 to 3,000 ft.

### 4-4. Embankment

Embankment sections adjacent to abutments may be flared to increase stability of sections founded on weak soils. Also, by flaring the core, a longer seepage path is developed beneath and around the embankment.

### 4-5. Abutments

*a. Alignments.* Alignments should be avoided that tie into narrow ridges formed by hairpin bends in the river or that tie into abutments that diverge in the downstream direction. Grouting may be required to decrease seepage through the abutment (see paragraph 3-1c). Zones of structurally weak materials in abutments, such as weathered overburden and talus deposits, are not uncommon. It may be more economical to flatten embankment slopes to attain the desired stability than to excavate weak materials to a firm foundation. The horizontal permeability of undisturbed strata in the abutment may be much greater than the permeability of the compacted fill in the embankment; therefore, it may be possible to derive considerable benefit in seepage control from the blanketing effects of flared upstream embankment slopes. The design of a transition from the normal embankment slopes to flattened slopes is influenced by stability of sections founded on the weaker foundation materials, drainage provisions on the slopes and within the embankment, and the desirability of making a gradual transition without abrupt changes of section. Adequate surface drainage to avoid erosion should be provided at the juncture between the dam slope and the abutment.

*b. Abutment slopes.* Where abutment slopes are steep, the core, filter, and transition zones of an embankment should be widened at locations of possible tension zones resulting from different settlements. Widening of the core may not be especially effective unless cracks developing in it tend to close. Even if cracks remain open, a wider core may tend to promote clogging. However, materials in the filter and transition zones are usually more self-healing, and increased widths of these zones are beneficial. Whenever possible, construction of the top 25 ft of an embankment adjacent to steep

abutments should be delayed until significant embankment and foundation settlement have occurred.

*c. Settlement.* Because large differential settlement near abutments may result in transverse cracking within the embankment, it may be desirable to use higher placement water contents (see paragraph 7-8a) combined with flared sections.

#### **4-6. Earthquake Effects**

The embankment and critical appurtenant structures should be evaluated for seismic stability. The method of analysis is a function of the seismic zone as outlined in ER 1110-2-1806. Damsites over active faults should be avoided if at all possible. For projects located near or over faults in earthquake areas, special geological and seismological studies should be performed. Defensive design features for the embankment and structures as outlined in ER 1110-2-1806 should be used, regardless of the type of analyses performed. For projects in locations of strong seismicity, it is desirable to locate the spillway and outlet works on rock rather than in the embankment or foundation overburden.

#### **4-7. Coordination Between Design and Construction**

*a. Introduction.* Close coordination between design and construction personnel is necessary to thoroughly orient the construction personnel as to the project design intent, ensure that new field information acquired during construction is assimilated into the design, and ensure that the project is constructed according to the intent of the design. This is accomplished through the report on engineering considerations and instructions to field personnel, preconstruction orientation for the construction engineers by the designers, and required visits to the site by the designers.

*b. Report on engineering considerations and instructions to field personnel.* To ensure that the field personnel are aware of the design assumptions regarding field conditions, design personnel (geologists, geotechnical engineers, structural engineers, etc.) will prepare a report entitled, "Engineering Considerations and Instructions for Field Personnel." This report should explain the concepts, assumptions, and special details of the embankment design as well as detailed explanations of critical sections of the contract documents. Instruction for the field inspection force should include the necessary guidance to provide adequate Government Quality Assurance Testing. This report should be augmented by appropriate briefings,

instructional sessions, and laboratory testing sessions (ER 1110-2-1150).

*c. Preconstruction orientation.* Preconstruction orientation for the construction engineers by the designers is necessary for the construction engineers to be aware of the design philosophies and assumptions regarding site conditions and function of project structures, and understand the design engineers' intent concerning technical provisions in the P&S.

*d. Construction milestones which require visit by designers.* Visits to the site by design personnel are required to ensure the following (ER 1110-2-112, ER 1110-2-1150):

(1) Site conditions throughout the construction period are in conformance with design assumptions and principles as well as contract P&S.

(2) Project personnel are given assistance in adapting project designs to actual site conditions as they are revealed during construction.

(3) Any engineering problems not fully assessed in the original design are observed, evaluated, and appropriate action taken.

*e. Specific visits.* Specifically, site visits are required when the following occur (ER 1110-2-112):

(1) Excavation of cutoff trenches, foundations, and abutments for dams and appurtenant structures.

(2) Excavation of tunnels.

(3) Excavation of borrow areas and placement of embankment dam materials early in the construction period.

(4) Observation of field conditions that are significantly different from those assumed during design.

#### **4-8. Value Engineering Proposals**

The Corps of Engineers has several cost-saving programs. One of these programs, Value Engineering (VE), provides for a multidiscipline team of engineers to develop alternative designs for some portion of the project. The construction contractor can also submit VE proposals. Any VE proposal affecting the design is to be evaluated by design personnel prior to implementation to determine the technical adequacy of the proposal. VE proposals must

not adversely affect the long-term performance or condition of the dam.

#### **4-9. Partnering Between the Owner and Contractor**

Partnering is the creation of an owner-contractor relationship that promotes achievement of mutually beneficial goals. By taking steps before construction begins to change the adversarial mindset, to recognize common interests, and to establish an atmosphere of trust and candor in communications, partnering helps to develop a cooperative management team. Partnering is not a contractual agreement and does not create any legally enforceable rights or duties. There are three basic steps involved in establishing the partnering relationship:

- a.* Establish a new relationship through personal contact.
- b.* Craft a joint statement of goals and establish common objectives in specific detail for reaching the goals.
- c.* Identify specific disputes and prevention processes designed to head off problems, evaluate performance, and promote cooperation.

Partnering has been used by the Mobile District on Oliver Lock and Dam replacement and by the Portland District on Bonneville Dam navigation lock. Detailed instructions concerning the partnering process are available in Edelman, Carr, and Lancaster (1991).